

What is claimed is:

1. A differential limiting control apparatus for a vehicle comprising:

5 an clutch unit interposed between one rotational shaft and the other rotational shaft for variably transmitting a driving force between the one rotational shaft and the other rotational shaft;

10 a target differential speed setting unit for setting a target differential speed between the one rotational shaft and the other rotational shaft,

an actual differential speed detecting unit for detecting an actual differential speed between the one rotational shaft and the other rotational shaft, and

15 a clutch torque computing unit for computing an engagement force of the clutch unit by obtaining a deviation between the target differential speed and the actual differential speed, configuring a switching function by using at least a polarity related to an 20 integral term of the deviation, and applying a sliding mode control.

2. The differential limiting control apparatus as set forth in Claim 1, wherein the switching function 25 configured at the clutch torque computing unit is such

as to result from adding a value obtained by multiplying  
a differential term of the deviation between the target  
differential speed and the actual differential speed by  
a predetermined gain to a value obtained by multiplying  
5 a value of the polarity by a predetermined gain.

3. The differential limiting control apparatus as  
set forth in Claim 1, wherein the clutch torque computing  
unit computes a final engagement force of the clutch unit  
10 by adding a value obtained by multiplying a proportional  
term of the deviation between the target differential  
speed and the actual differential speed by a  
predetermined gain to an engagement force of the clutch  
unit computed through the sliding mode control.

15

4. The differential limiting control apparatus as  
set forth in Claim 2, wherein the clutch torque computing  
unit computes a final engagement force of the clutch unit  
by adding a value obtained by multiplying a proportional  
20 term of the deviation between the target differential  
speed and the actual differential speed by a  
predetermined gain to an engagement force of the clutch  
unit computed through the sliding mode control.

25 5. The differential limiting control apparatus as

set forth in Claim 1, wherein;

the clutch unit is interposed between a front and a rear axles, wherein

the target differential speed setting unit sets a

5 target differential speed at least either one of between the front and rear axles, a left front wheel and a right front wheel, or a left rear wheel and a right rear wheel, wherein

the actual differential speed detecting unit

10 detects an actual differential speed at least either one of between the front and rear axles, the left front wheel and the right front wheel, or the left rear wheel and the right rear wheel which corresponds to the target differential speed setting unit, and wherein

15 the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting unit and an actual differential speed detected at the actual differential

20 speed detecting unit.

6. The differential limiting control apparatus as set forth in Claim 2, wherein;

the clutch unit is interposed between a front and a rear axles, wherein

the target differential speed setting unit sets a target differential speed at least either one of between the front and rear axles, a left front wheel and a right front wheel, or a left rear wheel and a right rear wheel,  
5 wherein

the actual differential speed detecting unit detects an actual differential speed at least either one of between the front and rear axles, the left front wheel and the right front wheel, or the left rear wheel and the right rear wheel which corresponds to the target differential speed setting unit, and wherein  
10

the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting unit and an actual differential speed detected at the actual differential speed detecting unit.  
15

7. The differential limiting control apparatus as set forth in Claim 1, wherein;  
20

the clutch unit is clutch unit for limiting a differential motion of a differential interposed between left and right wheels,

the target differential speed setting unit sets a target differential speed between the left and right  
25

wheels,

the actual differential speed detecting unit detects an actual differential speed between the left and right wheels, and

5 the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting unit and an actual differential speed detected at the actual differential  
10 speed detecting unit.

8. The differential limiting control apparatus as set forth in Claim 2, wherein;

the clutch unit is clutch unit for limiting a differential motion of a differential interposed between left and right wheels,

the target differential speed setting unit sets a target differential speed between the left and right wheels,

20 the actual differential speed detecting unit detects an actual differential speed between the left and right wheels, and

the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target  
25 speed detecting unit and

differential speed setting unit and an actual differential speed detected at the actual differential speed detecting unit.

5           9. The differential limiting control apparatus as set forth in Claim 1, wherein;

              the clutch unit is interposed between a front and a rear axles,

10          the target differential speed setting unit sets target differential speeds at least a plurality of between the front and rear axles, a left front wheel and a right front wheel, and a left rear wheel and a right rear wheel,

15          the actual differential speed detecting unit detects actual differential speeds at least a plurality of between the front and rear axles, the left front wheel and the right front wheel, and the left rear wheel and the right rear wheel which correspond to the target differential speed setting unit, and

20          the clutch torque computing unit computes a plurality of engagement forces of the clutch unit using target differential speeds set at the target differential speed setting unit and actual differential speeds detected at the actual differential speed detecting unit  
25          and computes one of the plurality of engagement forces

of the clutch unit which has a maximum value as a final engagement force of the clutch unit.

10. The differential limiting control apparatus  
5 as set forth in Claim 2, wherein;

the clutch unit is interposed between a front and a rear axles,

the target differential speed setting unit sets target differential speeds at least a plurality of 10 between the front and rear axles, a left front wheel and a right front wheel, and a left rear wheel and a right rear wheel,

the actual differential speed detecting unit detects actual differential speeds at least a plurality 15 of between the front and rear axles, the left front wheel and the right front wheel, and the left rear wheel and the right rear wheel which correspond to the target differential speed setting unit, and

the clutch torque computing unit computes a 20 plurality of engagement forces of the clutch unit using target differential speeds set at the target differential speed setting unit and actual differential speeds detected at the actual differential speed detecting unit and computes one of the plurality of engagement forces 25 of the clutch unit which has a maximum value as a final

engagement force of the clutch unit.

11. The differential limiting control apparatus as set forth in Claim 1, wherein the target differential speed setting unit sets in advance a lower limit value of the actual differential speed according to at least one of a vehicle speed, a lateral acceleration and an input torque inputted into the clutch unit and sets the target differential speed based on the lower limit value so set.

12. The differential limiting control apparatus as set forth in Claim 2, wherein the target differential speed setting unit sets in advance a lower limit value of the actual differential speed according to at least one of a vehicle speed, a lateral acceleration and an input torque inputted into the clutch unit and sets the target differential speed based on the lower limit value so set.

20

13. The differential limiting control apparatus as set forth in Claim 1, wherein the target differential speed setting unit selectively alter the target differential value that is set thereby.

25

14. The differential limiting control apparatus as set forth in Claim 2, wherein the target differential speed setting unit selectively alter the target differential value that is set thereby.

5

15. The differential limiting control apparatus as set forth in Claim 1, wherein the clutch torque computing unit leaves an engagement force of the clutch unit a preset value at least either one of when brakes 10 are applied or when an antilock braking system is in operation.

16. The differential limiting control apparatus as set forth in Claim 2, wherein the clutch torque 15 computing unit leaves an engagement force of the clutch unit a preset value at least either one of when brakes are applied or when an antilock braking system is in operation.

1'

20 17. A differential limiting control apparatus for a vehicle comprising:

a clutch unit interposed between one rotational shaft and the other rotational shaft for variably transmitting a driving force between the one rotational 25 shaft and the other rotational shaft;

1 a target differential speed setting unit for  
2 setting a target differential speed between the one  
3 rotational shaft and the other rotational shaft;

4 an actual differential speed detecting unit for  
5 detecting an actual differential speed between the one  
6 rotational shaft and the other rotational shaft; and

7 a clutch torque computing unit for computing an  
8 engagement force of the clutch unit by configuring a  
9 switching function having a term where a value of a  
10 polarity computed using an integral term based on at least  
11 a deviation between the target differential speed and  
12 the actual differential speed is multiplied by a  
13 predetermined gain and using a sliding mode control where  
14 when the switching function takes a positive value, the  
15 value of the switching function is used as a control  
value.

16 18. The differential limiting control apparatus  
17 as set forth in Claim 17, wherein the switching function  
18 configured at the clutch torque computing unit is such  
19 as to result from adding a value obtained by multiplying  
20 a differential term of the deviation between the target  
21 differential speed and the actual differential speed by  
22 a predetermined gain to a value obtained by multiplying  
23 a value of the polarity by a predetermined gain.

19. The differential limiting control apparatus  
as set forth in Claim 17, wherein the clutch torque  
computing unit computes a final engagement force of the  
5 clutch unit by adding an engagement force of the clutch  
unit computed through a proportional control based on  
the target differential speed and the actual differential  
speed to an engagement force of the clutch unit computed  
through the sliding mode control.

10

20. The differential limiting control apparatus  
as set forth in Claim 18, wherein the clutch torque  
computing unit computes a final engagement force of the  
clutch unit by adding an engagement force of the clutch  
15 unit computed through a proportional control based on  
the target differential speed and the actual differential  
speed to an engagement force of the clutch unit computed  
through the sliding mode control.

20 21. The differential limiting control apparatus  
as set forth in Claim 17, wherein;

the clutch unit is interposed between a front and  
a rear axles, wherein

the target differential speed setting unit sets a  
25 target differential speed at least either one of between

the front and rear axles, a left front wheel and a right front wheel, or a left rear wheel and a right rear wheel, wherein

the actual differential speed detecting unit  
5 detects an actual differential speed at least either one of between the front and rear axles, the left front wheel and the right front wheel, or the left rear wheel and the right rear wheel which corresponds to the target differential speed setting unit, and wherein

10 the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting unit and an actual differential speed detected at the actual differential  
15 speed detecting unit.

22. The differential limiting control apparatus as set forth in Claim 18, wherein;

the clutch unit is interposed between a front and  
20 a rear axles, wherein

the target differential speed setting unit sets a target differential speed at least either one of between the front and rear axles, a left front wheel and a right front wheel, or a left rear wheel and a right rear wheel,  
25 wherein

the actual differential speed detecting unit detects an actual differential speed at least either one of between the front and rear axles, the left front wheel and the right front wheel, or the left rear wheel and 5 the right rear wheel which corresponds to the target differential speed setting unit, and wherein

the clutch torque computing unit computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target 10 differential speed setting unit and an actual differential speed detected at the actual differential speed detecting unit.

23. The differential limiting control apparatus 15 as set forth in Claim 17, wherein;

the clutch unit is clutch unit for limiting a differential motion of a differential interposed between left and right wheels,

the target differential speed setting unit sets a 20 target differential speed between the left and right wheels,

the actual differential speed detecting unit detects an actual differential speed between the left and right wheels, and

25 the clutch torque computing unit computes an

engagement force of the clutch unit using a deviation  
between a target differential speed set at the target  
differential speed setting unit and an actual  
differential speed detected at the actual differential  
5 speed detecting unit.

24. The differential limiting control apparatus  
as set forth in Claim 18, wherein;

the clutch unit is clutch unit for limiting a  
10 differential motion of a differential interposed between  
left and right wheels,

the target differential speed setting unit sets a  
target differential speed between the left and right  
wheels,

15 the actual differential speed detecting unit  
detects an actual differential speed between the left  
and right wheels, and

the clutch torque computing unit computes an  
engagement force of the clutch unit using a deviation  
20 between a target differential speed set at the target  
differential speed setting unit and an actual  
differential speed detected at the actual differential  
speed detecting unit.

25. The differential limiting control apparatus

as set forth in Claim 17, wherein;

the clutch unit is interposed between a front and a rear axles,

the target differential speed setting unit sets 5 target differential speeds at least a plurality of between the front and rear axles, a left front wheel and a right front wheel, and a left rear wheel and a right rear wheel,

the actual differential speed detecting unit 10 detects actual differential speeds at least a plurality of between the front and rear axles, the left front wheel and the right front wheel, and the left rear wheel and the right rear wheel which correspond to the target differential speed setting unit, and

15 the clutch torque computing unit computes a plurality of engagement forces of the clutch unit using target differential speeds set at the target differential speed setting unit and actual differential speeds detected at the actual differential speed detecting unit 20 and computes one of the plurality of engagement forces of the clutch unit which has a maximum value as a final engagement force of the clutch unit.

26. The differential limiting control apparatus

25 as set forth in Claim 18, wherein;

the clutch unit is interposed between a front and a rear axles,

the target differential speed setting unit sets target differential speeds at least a plurality of 5 between the front and rear axles, a left front wheel and a right front wheel, and a left rear wheel and a right rear wheel,

the actual differential speed detecting unit detects actual differential speeds at least a plurality 10 of between the front and rear axles, the left front wheel and the right front wheel, and the left rear wheel and the right rear wheel which correspond to the target differential speed setting unit, and

the clutch torque computing unit computes a 15 plurality of engagement forces of the clutch unit using target differential speeds set at the target differential speed setting unit and actual differential speeds detected at the actual differential speed detecting unit and computes one of the plurality of engagement forces 20 of the clutch unit which has a maximum value as a final engagement force of the clutch unit.

27. The differential limiting control apparatus as set forth in Claim 17, wherein the target differential 25 speed setting unit sets in advance a lower limit value

of the actual differential speed according to at least one of a vehicle speed, a lateral acceleration and an input torque inputted into the clutch unit and sets the target differential speed based on the lower limit value 5 so set.

28. The differential limiting control apparatus as set forth in Claim 18, wherein the target differential speed setting unit sets in advance a lower limit value 10 of the actual differential speed according to at least one of a vehicle speed, a lateral acceleration and an input torque inputted into the clutch unit and sets the target differential speed based on the lower limit value so set.

15

29. The differential limiting control apparatus as set forth in Claim 17, wherein the target differential speed setting unit selectively alter the target differential value that is set thereby.

20

30. The differential limiting control apparatus as set forth in Claim 18, wherein the target differential speed setting unit selectively alter the target differential value that is set thereby.

25

31. The differential limiting control apparatus  
as set forth in Claim 17, wherein the clutch torque  
computing unit leaves an engagement force of the clutch  
unit a preset value at least either one of when brakes  
5 are applied or when an antilock braking system is in  
operation.

32. The differential limiting control apparatus  
as set forth in Claim 18, wherein the clutch torque  
10 computing unit leaves an engagement force of the clutch  
unit a preset value at least either one of when brakes  
are applied or when an antilock braking system is in  
operation.

15 33. A differential limiting control method for a  
vehicle having clutch unit interposed between one  
rotational shaft and the other rotational shaft for  
variably transmitting a driving force between the one  
rotational shaft and the other rotational shaft,  
20 comprising steps of:

setting a target differential speed between the one  
rotational shaft and the other rotational shaft,  
detecting an actual differential speed between the  
one rotational shaft and the other rotational shaft, and  
25 computing an engagement force of the clutch unit

by obtaining a deviation between the target differential speed and the actual differential speed, configuring a switching function by using at least a polarity related to an integral term of the deviation, and applying a  
5 sliding mode control.

34. The differential limiting control method as set forth in Claim 33, wherein the switching function configured at the clutch torque computing step is such  
10 as to result from adding a value obtained by multiplying a differential term of the deviation between the target differential speed and the actual differential speed by a predetermined gain to a value obtained by multiplying a value of the polarity by a predetermined gain.

15

35. The differential limiting control method as set forth in Claim 33, wherein the clutch torque computing step computes a final engagement force of the clutch unit by adding a value obtained by multiplying a proportional  
20 term of the deviation between the target differential speed and the actual differential speed by a predetermined gain to an engagement force of the clutch unit computed through the sliding mode control.

25 36. A differential limiting control method for a

vehicle having clutch unit interposed between one rotational shaft and the other rotational shaft for variably transmitting a driving force between the one rotational shaft and the other rotational shaft,  
5 comprising steps of:

setting a target differential speed between the one rotational shaft and the other rotational shaft;

detecting an actual differential speed between the one rotational shaft and the other rotational shaft; and

10 computing an engagement force of the clutch unit by configuring a switching function having a term where a value of a polarity computed using an integral term based on at least a deviation between the target differential speed and the actual differential speed is multiplied by a predetermined gain and using a sliding mode control where when the switching function takes a positive value, the value of the switching function is used as a control value.

20 37. The differential limiting control method as set forth in Claim 36, wherein the switching function configured at the clutch torque computing step is such as to result from adding a value obtained by multiplying a differential term of the deviation between the target differential speed and the actual differential speed by  
25

a predetermined gain to a value obtained by multiplying a value of the polarity by a predetermined gain.

38. The differential limiting control method as  
5 set forth in Claim 36, wherein the clutch torque computing step computes a final engagement force of the clutch unit by adding an engagement force of the clutch unit computed through a proportional control based on the target differential speed and the actual differential speed to  
10 an engagement force of the clutch unit computed through the sliding mode control.

39. The differential limiting control method as  
set forth in Claim 33, wherein;  
15 the clutch unit is interposed between a front and a rear axles, wherein  
the target differential speed setting step sets a target differential speed at least either one of between the front and rear axles, a left front wheel and a right front wheel, or a left rear wheel and a right rear wheel,  
20 wherein

the actual differential speed detecting step detects an actual differential speed at least either one of between the front and rear axles, the left front wheel and the right front wheel, or the left rear wheel and  
25 the right rear wheel,

the right rear wheel which corresponds to the target differential speed setting step, and wherein

the clutch torque computing step computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting step and an actual differential speed detected at the actual differential speed detecting step.

10 40. The differential limiting control method as set forth in Claim 33, wherein;

the clutch unit is clutch unit for limiting a differential motion of a differential interposed between left and right wheels,

15 the target differential speed setting step sets a target differential speed between the left and right wheels,

the actual differential speed detecting step detects an actual differential speed between the left 20 and right wheels, and

the clutch torque computing step computes an engagement force of the clutch unit using a deviation between a target differential speed set at the target differential speed setting step and an actual differential speed detected at the actual differential

speed detecting step.

41. The differential limiting control method as set forth in Claim 33, wherein;

5 the clutch unit is interposed between a front and a rear axles,

the target differential speed setting step sets target differential speeds at least a plurality of between the front and rear axles, a left front wheel and 10 a right front wheel, and a left rear wheel and a right rear wheel,

the actual differential speed detecting step detects actual differential speeds at least a plurality of between the front and rear axles, the left front wheel 15 and the right front wheel, and the left rear wheel and the right rear wheel which correspond to the target differential speed setting step, and

the clutch torque computing step computes a plurality of engagement forces of the clutch unit using 20 target differential speeds set at the target differential speed setting step and actual differential speeds detected at the actual differential speed detecting step and computes one of the plurality of engagement forces of the clutch unit which has a maximum value as a final 25 engagement force of the clutch unit.

42. The differential limiting control method as set forth in Claim 33, wherein the target differential speed setting step sets in advance a lower limit value 5 of the actual differential speed according to at least one of a vehicle speed, a lateral acceleration and an input torque inputted into the clutch unit and sets the target differential speed based on the lower limit value so set.

10

43. The differential limiting control method as set forth in Claim 33, wherein the target differential speed setting step selectively alter the target differential value that is set thereby.

15

44. The differential limiting control method as set forth in Claim 33, wherein the clutch torque computing step leaves an engagement force of the clutch unit a preset value at least either one of when brakes are 20 applied or when an antilock braking system is in operation.